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ORIGINAL

Quantitative Analysis of Academic Performance and Temporal Efficiency Using Virtual Simulation Based on Case Studies: Monitoring Learning Outcomes with a Focus on Evaluative Metadata

Análisis cuantitativo del rendimiento académico y eficiencia temporal mediante simulación virtual basada en estudios de caso: seguimiento de resultados de aprendizaje con enfoque en metadatos evaluativos

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ABSTRACT

Introduction: digital platforms currently facilitate the recording of metadata relevant to learning monitoring. In higher education, it is feasible to apply resolution time and grades obtained in virtual environments as indicators of efficiency and academic performance.
Method: the research was quantitative in nature. The study was descriptive and quasi-experimental. The population consisted of 152 students enrolled in the online early childhood education programme at the National University of Education in Ecuador. A non-probabilistic, intentional and selective sample of 29 students was used. A virtual assessment simulator was developed on the Moodle platform for data collection. A method was developed to compare resolution time records (automatic metadata) and the grades obtained (pre-test and post-test).
Results: after the intervention, a notable improvement in grades was observed (mean pre-test = 6,79; mean post-test = 8,28; $t = -5,711$; $p < 0,001$). The average time spent decreased from 29 minutes 12 seconds to 22 minutes 11 seconds ($t = 45,241$; $p < 0,001$), indicating higher temporal efficiency. Pearson's correlation showed a weak and non-significant association between time spent and final grade ($r = 0,199$; $p = 0,300$). Patterns of efficiency throughout the assessment were described using scatter plots.
Conclusion: the study demonstrated the analytical potential of metadata as evaluative analysis tools. Virtual simulation succeeded in optimising students' academic performance. It is recommended that metadata be used to personalise teaching strategies, promote data-driven teaching decisions, and create more adaptive and equitable environments.

Keywords: Educational Metadata, Virtual Simulation; Academic Efficiency; Data-Driven Decision-Making; Learning Assessment; Correlation Analysis.

RESUMEN

Introducción: actualmente las plataformas digitales facilitan el registro de metadatos relevantes para el seguimiento del aprendizaje. En educación superior, es factible aplicar el tiempo de resolución y las calificaciones obtenidas en entornos virtuales como indicadores de eficiencia y desempeño académico.

Método: la investigación fue de carcater cuantitativo. El estudio fue descriptivo y cuasiexperimental. La población estuvo constituida por 152 estudiantes matriculados en el programa de educación de la primera infancia en línea de la Universidad Nacional de Educación de Ecuador. Se utilizó un muestreo no probabilístico, de tipo intencional y selectivo con 29 estudiantes. Se desarrolló un simulador de evaluación virtual en la plataforma Moodle para la recopilación de datos. Se desarrolló un método para comparar los registros de tiempo de resolución (metadatos automáticos) y las calificaciones obtenidas (pre-test y post-test).
Resultados: después de la intervención, se observó una notable mejoría en las calificaciones (media pre-test = 6,79; media post-test = 8,28; t = −5,711; p < 0,001). El tiempo promedio empleado disminuyó de 29 minutos 12 segundos a 22 minutos 11 segundos (t = 45,241; p < 0,001), lo que indica una mayor eficiencia temporal. La correlación de Pearson mostró una asociación débil y no significativa entre el tiempo dedicado y la calificación final (r = 0,199; p = 0,300). Los patrones de eficiencia a lo largo de la evaluación se describieron utilizando diagramas de dispersión.
Conclusión: el estudio demostró el potencial analítico de los metadatos como herramientas de análisis evaluativo. La simulación virtual logró optimizar el rendimiento académico de los estudiantes. Se recomienda que los metadatos se utilicen para personalizar las estrategias de enseñanza, promover decisiones de enseñanza basadas en datos y crear entornos más adaptables y equitativos.

Palabras clave: Metadatos Educativos; Simulación Virtual; Eficiencia Académica; Toma de Decisiones Basada en Datos; Evaluación del Aprendizaje; Análisis de Correlación.

INTRODUCTION

In recent years, several universities in Northern Europe and Asia have made significant progress in integrating virtual learning environments. Institutions such as the University of Helsinki and the University of Tokyo have opted for assessment models based on digital simulations with positive results.[1,2,3] These strategies have led to improvements in students' response times and an increase in the accuracy of their answers. The data was collected through platforms that integrate automated analysis tools. These systems not only reduced the workload for teachers but also provided immediate feedback.[4,5,6] In addition, countries such as South Korea and Denmark applied mechanisms to track learning outcomes, prioritising the analysis of metadata as input for academic decision-making. These experiences were consolidated in digital ecosystems where statistics on exam times and performance became key indicators for reformulating teaching practice.[7,8,9]

In Latin America, some universities have attempted to replicate virtual simulator practices in assessments. The University of São Paulo implemented a simulation-based assessment system. This system led to improvements in the quality of students' responses.[10] In Colombia, the National University used the Moodle platform with interactive simulations. These integrated case studies, and a progressive improvement in critical skills were observed. Despite these initiatives, academic and assessment strategies are limited. Many universities lack organised data and systematic analysis research.[11]

Traditional tests are often prioritised, with results that do not adequately reflect student performance.[12] The lack of continuous monitoring and quantitative analysis prevents informed decisions from being made by educational management. While good practices exist, access to technology, teacher training, and assessment culture are still persistent challenges across much of the continent.[10]

In Ecuador, the scenario presents similar challenges. The use of virtual simulators to measure academic performance is still sporadic. Although platforms such as Moodle are available in many universities, their potential for assessment monitoring remains underutilised.[13,14,15] There are no studies that integrate response time as relevant metadata for assessing student efficiency. Nor has any research been conducted comparing assessment moments in the same group using different application methods.

The National University of Education (UNAE) has used traditional models to carry out its assessments. Despite the existence of digital tools, these have not been systematised for academic research. As a result, no comparative databases have been developed to analyse student progress in their performance using active methodologies. If this continues, there is a risk of entering into pedagogy without the necessary empirical foundation. The benefits of distance learning and training are lost.

Effective feedback is scarce, and temporal efficiency as an indicator of progress becomes invisible. The absence of studies with quantitative analysis in this context represents a clear academic gap. It is essential to build local evidence to support the redesign of data-based assessment strategies.

Within this framework, the following research question arose:

Does the application of virtual simulations oriented towards case studies improve academic performance and reduce response time among fourth-cycle university students at UNAE, when comparing two different

assessment moments?

Based on this question, the following general objective of the study was defined:

To analyse the impact of the implementation of virtual simulations oriented towards case studies on the improvement of academic performance and time efficiency of fourth-cycle university students, through quantitative monitoring of learning outcomes between two assessment moments. To respond to the objective formulated, the study sought to verify whether the application of virtual simulations with case studies would be associated with measurable variations in academic performance and response time among students.

METHOD

Research approach

The study adopted a quantitative approach.

Type of research

The research design was quasi-experimental, descriptive and correlational. The study compared the performance of the same group before and after a pedagogical intervention.[17] At the descriptive level, the behaviour of the observed variables was characterised. At the correlational level, the associations between academic performance and resolution time were explored. This type of design was ideal for evaluating the effect of a teaching strategy on a specific group without random assignment.

Population and sample

The selection was non-probabilistic, intentional, and selective, as participants were chosen based on their availability and relevance to the objectives of the study rather than through random sampling.[18] This approach was appropriate because the study aimed to analyse a specific academic cohort with shared curricular characteristics and access to the same virtual learning environment.

Inclusion criteria

Students officially enrolled in the fifth cycle of the Early Childhood Education programme, who had completed all previous courses, participated in both pre-test and post-test assessments, and were eligible to take the national CACES evaluation.

Exclusion criteria

Students with incomplete registration, deferred subjects, or inconsistent participation in the virtual activities were excluded to ensure homogeneity and validity of the comparison between assessment moments.

The final sample consisted of 29 students who met all inclusion criteria, ensuring the comparability and reliability of the results obtained.

Techniques and instruments

The technique applied was structured observation with digital support. The instrument consisted of two virtual exams. The first (pre-test) was designed with closed, direct questions without situational contextualisation. It responded to a traditional assessment approach based on memorisation and content recognition. In contrast, the second (post-test) incorporated practical cases applied to real contexts of the early childhood education degree programme. Each question required analysis, decision-making, and pedagogical application. This restructuring sought to highlight the in-depth use of knowledge.[7,13]

It is important to note that, before the second test, students received virtual guidance from their teachers. These online sessions served to guide case resolution, clarify methodological doubts, and reinforce comprehensive reading strategies. This support was provided on the same Moodle platform, EVEA-UNAE (Virtual Learning Environment), which allowed for the virtual continuity of the process. Both instruments were designed in line with the learning outcomes of the current curriculum. They were then validated by a panel of three expert judges — two specialists in educational measurement and one in early childhood pedagogy — all with more than five years of experience in higher education assessment. The validation process followed the expert judgment method, using a structured checklist that evaluated each item's relevance, clarity, and cognitive depth according to the current curriculum standards. Each evaluator rated the items on a four-point scale, and the global agreement index among judges reached 0,89, indicating a high level of concordance. Minor linguistic adjustments were made based on their feedback to improve item precision and readability. The exams were hosted on Moodle. This platform automatically recorded the time spent by each student in completing the assessment. This data was key to the analysis of time efficiency.

Results analysis techniques

SPSS statistical software, version 26, was used for data processing. The student's t-test for related samples

was applied to compare the means obtained at the two assessment points.[19] This test was key to verifying whether there were significant differences in scores and response times. Pearson's correlation coefficient was also calculated. This made it possible to identify whether there was a direct relationship between the time spent on the exam and the level of academic performance.

As for the theoretical analysis, a hermeneutic review of scientific studies no more than five years old, available in the Scopus-Elsevier database, was used. This made it possible to compare the findings with recent research on educational simulations and virtual environments.[20] The results were interpreted using the ethical principles established by the Committee on Publication Ethics (COPE). Data confidentiality was ensured by applying an anonymous coding system. No names, surnames or direct identifiers of the students were included. This measure ensured respect for the privacy and integrity of the participants.[21]

RESULTS

To evaluate the impact of a pedagogical strategy based on practical case simulations and virtual teaching support, two assessments were carried out on a group of 29 students. The analysis focused on two main indicators: the difference in scores (Diff_Quiz) and the difference in time spent on the task (Diff_Time), both obtained by subtracting the second attempt from the first (post-test – pre-test). The data were processed in SPSS, using parametric statistical tests.

Tests of normality

Before applying inferential tests, the distribution of differences was checked using the Kolmogorov-Smirnov and Shapiro-Wilk normality tests. The results showed non-significant values in both tests for the two variables ($p > 0,05$), indicating that the data have an acceptable normal distribution (see table 1).

Table 1. Tests of normality Kolmogorov-Smirnov[a] and Shapiro-Wilk

Tests of normality					
	Kolmogorov-Smirnov			Shapiro-Wilk	
	Statistic	df	Sig.	Statistic	Sig.
Diff_Quiz	,158	29	,062	,950	,186
Diff_Time	,118	29	,200*	,962	,369

* This is a lower limit of true significance.
[a]. Lilliefors Correction of Significance.

Academic performance

The results showed a significant improvement in grades after the intervention. In the first attempt, the average was 6,79 points, while in the second it rose to 8,28. The mean difference (Diff_Quiz) was +1,48 points, with a standard deviation of 1,398 (see table 2). This change was statistically significant according to the Student's t-test for related samples ($t = -5,711$; $p < 0,001$).

Table 2. Student's t-test for related samples

Paired Samples Test		Paired Differences					t	df	Sig. (2-tailed)
Pair	Variables	Mean	Std. Deviation	Std. Error Mean	95 % Confidence Interval				
					Lower	Upper			
1	Quiz.results.1 Quiz. results.2	-1,4828	1,3982	,2596	-2,0146	-,9509	-5,711	28	,000
2	Exam.time.1 -Exam. time.2	0:07:00	0:00:50	0:00:09	0:06:41	0:07:19	45,241	28	,000

This finding demonstrates that the pedagogical strategy used produced a real improvement in students' academic performance.

Resolution time behaviour

There was also a notable change in the average time taken to complete the exam. For the pretest, the average time was 29 minutes and 12 seconds, while for the posttest it was 22 minutes and 11 seconds. These results showed an average difference of exactly seven minutes. This difference was statistically significant, according to the t-test ($t = 45,241$; $p < 0,001$).

General comparison

The application of Student's t-test for related samples indicated that the differences observed in both grades and times were statistically significant (see table 2). The results allow us to conclude that the strategy based on practical cases, reinforced with virtual advice and a simulator, had a positive impact on both dimensions evaluated: performance and efficiency.

Correlation analysis

To identify whether there was a relationship between the improvement in grades and the reduction in resolution time, Pearson's correlation coefficient was applied between Diff_Quiz and Diff_Time. The result was r = 0,199 with p = 0,300, indicating a weak and insignificant positive correlation (see Table 3).

Table 3. Pearson Correlation Matrix between Diff_Quiz and Diff_Time

Correlation			
		Diff_Quiz	**Diff_Time**
Diff_Quiz	Pearson Correlation	1	,199
	Sig. (2-tailed)		,300
	N	29	29
Diff_Time	Pearson Correlation	,199	1
	Sig. (2-tailed)	,300	
	N	29	29

This result suggests that there is no direct relationship between the degree of improvement in grades and the number of minutes saved.

Visualisation of the relationship

To illustrate this relationship graphically, a scatter plot with a regression line was constructed, showing a slightly negative slope and a wide confidence interval, reinforcing the weakness of the link between the two variables (see figure 1).

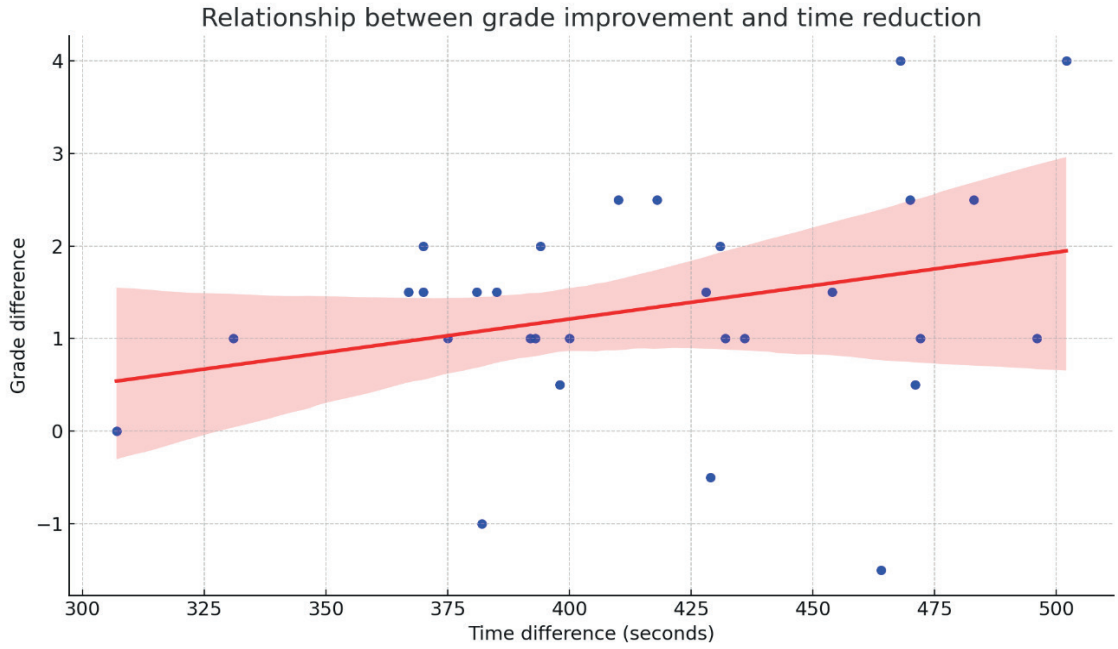

Figure 1. Scatter Plot with Regression Line: Relationship Between Grade Improvement and Time Reduction

Academic performance (as measured by the difference in grades) is plotted against resolution time (as measured in seconds) in the scatter plot, figure 1. The trend line displays a slight negative slope, implying a general tendency that students who spent less time on the second attempt achieved better scores. Nonetheless, the wide confidence interval points to a high dispersion of data and a weak relationship. This corresponds with the previously calculated Pearson correlation coefficient (r = 0,199; p = 0,300) which was also statistically non-

significant. In practical terms, time reduction and grade improvement may be linked, but not conclusively. This implies that the other factors influencing time improvement on the task may well be conceptual understanding or the level of prior practice, or familiarity with the exam format, or other aspects that were not studied in this analysis.

DISCUSSION

Any data-based analysis process requires a clear understanding of the relationships between variables, their changes following an intervention, and the patterns they reveal. This study identified significant variations in academic performance and time efficiency after applying a pedagogical strategy based on simulations and virtual support.[8,9,12] This empirical evidence, obtained using statistical tools, confirmed the relevance of the proposed quasi-experimental approach. The results showed that students significantly improved their grades. The positive average difference in scores, together with a low standard deviation, indicated consistency across cases. This homogeneity in academic improvement suggests that the digital resolution environment, as well as the type of instruction, had a favourable effect on content comprehension. From a data science perspective, this type of trend is valuable for identifying replicable educational practices.[3,22,23]

When comparing this finding with recent studies on digital learning, a clear coincidence was observed. Research applied to virtual higher education environments confirmed that the inclusion of contextualised cases and teacher feedback have a direct impact on knowledge acquisition. This coincidence validates the application of the adopted model. Furthermore, the internal consistency between results strengthens confidence in the recorded data and allows for replicable projections.[2,24,25] On the other hand, the significant reduction in average resolution time showed an improvement in time management by students. This reduction was not due to unproductive urgency, but rather to a greater level of familiarity with the platform, clarity in instruction, and the development of reading and analysis strategies.[26,27] In terms of temporal metadata, the decrease in minutes suggests a change in response habits, possibly associated with prior training and the restructuring of the assessment instrument.[4,5,15,28]

The relationship between academic performance and resolution time was not statistically significant. This lack of direct correlation can be explained by differential learning theory. Some students achieved high scores without drastically reducing their time, while others reduced their time without improving their scores by the same proportion. This non-linear behaviour reaffirms the multifactorial nature of academic performance. The interpretation of this variability leads us to consider additional factors not covered in this study, such as type of reasoning, familiarity with the digital environment, or degree of self-confidence.[29] The absence of a significant correlation can also be interpreted from a holistic view of online learning. Virtual environments promote a different type of processing, where speed is not always related to depth. This characteristic was evident in the data obtained. The r value close to zero showed a weak and uncertain trend. This finding, far from invalidating the intervention, highlights the inherent complexity of analysing educational behaviour on digital platforms.

Furthermore, when analysing the distribution of differences through normality tests, it was found that both variables behaved appropriately for the use of parametric tests.[14] This methodological verification, often omitted in educational studies, provided statistical robustness to the analytical process. From a data-driven decision-making perspective, validating normality prior to the t-test reinforces the credibility of the results obtained and avoids type I or II errors in inference.[2] Recent studies focused on educational data mining have highlighted the importance of integrating temporal and performance analyses to generate early warnings and personalised recommendations. Although the sample size was limited, this study contributed to this line of research by combining academic scores with automated time records in Moodle. This integration of operational data with cognitive results is a practical example of multidimensional analysis aimed at continuous improvement.[1,7,11,30]

Likewise, the use of tools such as Pearson's coefficient and histograms contributed to visualising student trajectories. In digital assessment environments, these visualisations support pedagogical decision-making. By reviewing the data, a teacher could identify students who require specific support or reinforcement strategies. This practical application of educational metadata justifies the need to include analytical processes as an integral part of feedback cycles in universities. The final interpretation suggests that the strategy implemented was effective in generating observable improvements. However, the heterogeneity of responses among students highlights the importance of designing personalised interventions.[26] Data should be interpreted not as absolute truths, but as paths to understanding. In this sense, the usefulness of SPSS was valued for integrating individual values, group averages and relationships between variables, thus complying with the principles of traceability and transparency in data-based research.

This discussion allows us to affirm that university pedagogy, in digital contexts, can benefit significantly from structured data analysis. It is not enough to obtain grades; it is necessary to interpret them considering the context, user behaviour and platform design. The methodological strategy employed here allowed us to extract value from digital records, identifying useful patterns for academic planning and the improvement of virtual

teaching. These findings contribute not only to strengthening students' cognitive health, but also to closing structural gaps in educational equity.

Limitations

- The study was conducted with a relatively small and homogeneous sample of 29 students from a single academic programme. The sample limits the generalisation of the results to other educational contexts or disciplines.
- The quasi-experimental design did not include a control group, making it difficult to isolate the specific influence of the intervention from contextual factors such as prior knowledge or digital familiarity.
- The research was based solely on quantitative data obtained from grades and completion times. No qualitative evidence was collected to understand students' perceptions, motivation, or cognitive processes during virtual tasks.
- The intervention was of limited duration, which prevented the observation of long-term effects on learning retention or academic transfer.
- The analyses were performed statistically, and measurement biases may have occurred due to the automatic data recording system.
- It is recommended that future research address these limitations through mixed designs, larger and more diverse samples, and longitudinal follow-up to strengthen the external validity and robustness of the results.

CONCLUSION

The findings indicate that the use of case-based pedagogy with virtual assistance positively impacted two dimensions: students' academic achievement and students' efficiency with the assignment completion time. This finding directly addresses the first objective of the study, which examined performance at two different times. The improvement of students' grades and the time taken to complete the assignments illustrates the effectiveness of the strategy. With respect to the second objective of the study, which examined the relation, if any, between the performance and the time spent on the assignment, the conclusion arrived at was that the two variables either did not relate directly, or at all, and that statistically the relation was insignificant. This finding confirmed that no statistically significant relationship was found between the two variables. The gap between individual student performance pathways underscored the need for individualized explanation and, perhaps, differentiated instruction, and not to take results at face value.

Deficiencies in the study included the small sample size and the absence of qualitative variables that might indicate and deepen the understanding of the user experience. The research did not consider variables described as affective, motivational, or contextual that might have influenced performance. It is also suggested that data mining algorithms be applied to identify clusters of students based on behavioural patterns. This type of analysis would strengthen evidence-based decision-making by teachers and improve the effectiveness of virtual learning environments.

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